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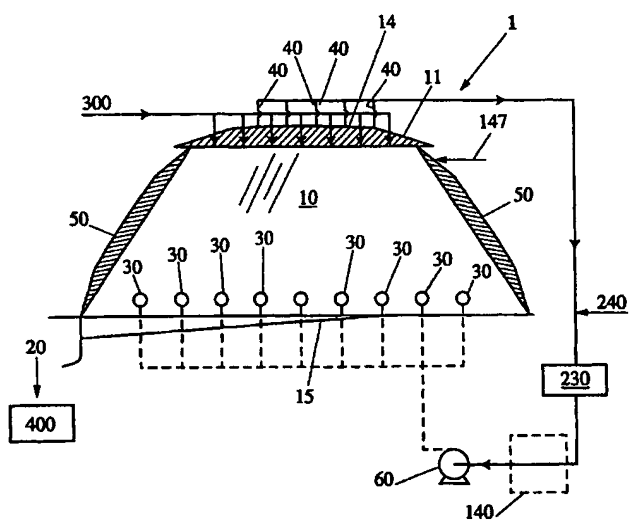
(54) Title: AN IMPROVED METHOD FOR HEAP LEACHING OF CHALCOPYRITE



(57) Abstract: Disclosed is a method for heap leaching an ore containing chalcopyrite. Acidic liquor containing iron or sulphur oxidising bacteria is introduced to a heap containing chalcopyrite ore for contacting with that ore. Such contacting will liberate copper from the ore. During this process, an oxygen-containing gas is introduced to the heap as a source of oxygen for the bacteria. The oxygen-containing gas is introduced to a heap having saturation and temperature controlled to maintain a substantial portion of the heap at a temperature such that thermophilic bacteria leach the chalcopyrite at an economically acceptable rate. A heap leaching system (1) operating in accordance with the method is also disclosed.

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AN IMPROVED METHOD FOR HEAP LEACHING OF CHALCOPYRITE

Field of the Invention

This invention relates to methods and systems for heap leaching of copper ores; and, in particular, to a method for heap leaching an ore containing chalcopyrite.

Background to the Invention

Chalcopyrite is a copper mineral having the formula $CuFeS_2$. Ore containing chalcopyrite usually contains about 0.1% to 5% copper, which may be a useful source of copper because there are large resources of chalcopyrite ore. Such resources may not be economically treatable by smelting routes. Further, as sulphur must be removed by roasting or other techniques, processes involve capital-intensive sulphur dioxide treatment or conversion stages. Therefore, a hydrometallurgical process which avoids the need for sulphur dioxide handling would be preferred.

Bacterial leaching is a possible process for this application as are acid leaching processes which involve heap leaching with an acidic liquor which may contain bacteria. A problem with current methodology is that leaching rates of chalcopyrite are slow whether or not bacteria are present. Without wishing to be bound by any theory, it is possible that occlusion of ore particles with jarosite deposits which are intractable to bacterial leaching is involved.

Therefore, heap leaching of chalcopyrite containing ores has commonly been confined to leaching of waste dumps associated with existing operations because waste dump leaching is not generally economically sensitive to time taken for copper recovery.

Chalcopyrite ores may be mixed with iron deficient containing copper sulphides such as chalcocite, bornite and covellite in an effort to more broadly apply bacterial heap leaching methodology. However, though extraction rates and recovery may be enhanced, where chalcopyrite predominates, possibly due to the action of ferric ions liberated by the leaching process, rates tend to be slow and final extraction low.

In conventional heap leaching with acid and bacteria, a liquor containing the acid and bacteria is sprayed or otherwise introduced to the heap and allowed to percolate through it. Copper is thereby leached from the copper

minerals present in the ore with a copper-containing solution being recovered from the bottom of the heap for further processing.

Air may be introduced to the heap to assist the function of the bacteria and accelerate the rate of leaching. In such a process, the temperatures in the heap typically range between 30°C and 50°C due to factors such as:

(a) the energy balance over the heap which is governed by such factors as the convective and evaporative heat losses from the heap; and

(b) the heaps are not inoculated with bacteria that can function at higher temperatures, hence making the heap "self-regulating" around the temperature at which the bacteria operate.

. In this temperature range, mesophilic bacteria expected to be present are *Thiobacillus ferrooxidans, Thiobacillus thiooxidans, Leptospirillum ferrooxidans* and unnamed moderately thermophilic bacteria. Such bacteria will only assist slow leaching of heap minerals and high extraction levels would not be expected.

In an effort to address the twin problems of slow extraction and low recovery, researchers have, since the 1970s and early 1980s turned attention to leaching of chalcopyrite with extreme thermophilic bacteria. Such work has been reported, for example, by Brierley, C.L. and Muir, L.E. (1973) *Leaching: Use of Thermophiles and Chemoautotrophic Microbes* and Brierley, C.L. (1980) *Leaching of Chalcopyrite Ore using Sulpholobus Species.* This work has been confined to column leaching studies that have not established any commercially acceptable methodology for using thermophilic bacteria in the leaching of chalcopyrite.

In the heap leaching context, as well established by literature, there is a wide variation in temperature throughout the heap and this has detrimental effects since bacterial species most suitable for leaching of chalcopyrite will not remain viable or at optimum growth in all regions of the heap. Extraction efficiencies and overall extraction rates are therefore consequently lowered.

Summary of the Invention

It is the object of the present invention to provide an economic treatment route for heap leaching of ores containing chalcopyrite.

With this object in view, there is provided a method for heap leaching an ore containing chalcopyrite including the steps of:

(a) introducing an acidic liquor containing iron or sulphur oxidising bacteria to a heap including chalcopyrite ore for contacting with the ore for liberating copper therefrom; and

(b) introducing an oxygen-containing gas to the heap through an aeration system as a source of oxygen for the bacteria wherein the oxygen-containing gas introduced to the heap has saturation and temperature controlled to maintain a substantial portion of the heap at a temperature such that thermophilic bacteria leach the chalcopyrite ore at an economically acceptable rate which makes operation of the process economically viable.

The temperature of the substantial portion of the heap is advantageously maintained in an extreme thermophilic temperature range at a temperature greater than 60°C, a temperature at which the extreme thermophilic bacteria thrive. By extreme thermophilic bacteria may be understood those iron and sulphur oxidising bacteria having optimum growth temperature above about 60°C, more particularly above 70°C. The actual temperature or temperature range may vary from this, within the range 60°C to 90°C, depending on the particular thermophile involved in the leach.

Notably, bacteria of the *Sulpholobus* species are active in this temperature range. So, optimum growth and viability, as well as chalcopyrite oxidation rate, would be expected to be achieved in this temperature range. Such bacteria may be isolated from a number of locations such as coal mines and hot springs, as described - for example - in United States Patent No. 4729788, directed to recovery of precious metals such as gold and silver from refractory sulphidic materials rather than treatment of chalcopyrite ores, the contents of which are hereby incorporated by reference.

Moderate thermophilic microorganisms may alternatively be employed in the process. Such moderate thermophilic organisms have a moderate thermophilic temperature range or an optimum growth temperature of between about 50°C and about 60°C. In this case, the heap is to be maintained in the temperature range about 50°C to about 60°C.

Microorganisms employed in the method of the invention may have one or both of iron oxidising and sulphur oxidising capability.

The oxygen-containing gas of preference is air (though oxygen or air/oxygen mixtures could also be used with admixture of carbon dioxide as a carbon source as necessary). Other oxygen-containing gases, modified with carbon dioxide as appropriate, may be used subject to suitability as a source of bacterial oxygen.

The oxygen-containing gas is at least partially saturated with water; and heated to a temperature for use in temperature control of the heap in the following manner. The flow of air through the heap transfers the heat liberated by bacterial oxidative activity to cooler regions of the heap. This process may be assisted by maintaining temperature of the oxygen-containing gas such as air by heating means, for example at a gas temperature above about 40°C prior to introduction to the heap. Maximum temperature of about 60°C should not be exceeded on introduction of gas to the heap. An ideal temperature range for extreme thermophiles would be between 45°C and 55°C with introduction at about 50°C being most preferred.

Where moderate thermophiles are used in the process, saturated air would be introduced to the heap at a temperature maintained, by heating or otherwise, above about 30°C, preferably in the range 35°C to 40°C. In this case, the temperature may rise and less insulation of the heap may be required. In addition, provision for cooling may be required at the top portion of the heap. Such cooling may be achieved by allowing more evaporation from the heap; and possibly introducing additional cool air to the heap at a top portion thereof possibly at the point where the temperature increases above the temperature at which bacteria are viable.

Saturation of the gas is ideally a high saturation with water, preferably substantially full saturation, as evaporation of the contained water consumes heat in those high temperature regions of the heap in which temperature excursions above tolerance of known thermophiles may reduce leaching efficiency and rate. In this manner, the heap temperature may be maintained or "buffered" in the temperature range conducive to optimal extreme thermophile

activity and leaching rates. Temperature at the top of the heap is expected not to exceed 90°C and may be expected to be in the range 80-90°C because of the latent heat consumed in evaporation of water.

Put another way, the temperature and saturation of oxygen-containing gas introduced to the heap is conditioned, possibly by use of a heating/humidity control stage (which may take the form of a humidification/dehumidification system or humidifier/dehumidifier) such that a substantial portion of the heap, most desirably the whole heap, is maintained at a temperature and saturation conducive to optimal oxidative activity of extreme or moderate thermophilic organisms throughout the heap leach process. Saturation is controlled to be at a pre-determined value selected to maintain economically acceptable leaching rates in the heap. Either of humidification and/or dehumidification of gas may be allowed for.

Maintenance of this desired temperature range may be facilitated by insulating the heap to minimise heat loss. As the heap is exposed to atmosphere and heat loss is greatest at the top and sides of the heap, insulation in this region is highly desirable. Insulation at the heap bottom is also possible. In a simple embodiment, an open curtain type or cover of suitable material, typically with insulating properties may be employed in these top and/or side regions. The cover is advantageously water impermeable.

Various insulating materials may be used for this application. Both synthetic and naturally occurring insulating materials may be used for this application.

In a particular embodiment of the present invention, an inert insulative substrate layer such as a waste or overburden rock layer may be used as an insulative layer. Such rock layer(s) may be arranged relative to the leachable ore, above, below and / or at the sides of a heap of leachable ore. Multiple layers, of same or different materials may be employed. Insulating blankets of other material may be employed as an alternative or to supplement the insulative effect.

The rock or insulative substrate or insulative material layers, any desired number of which may be provided, may act as heat transfer mediums which

provide zones for humidification of air, or other oxygen containing gas, entering the heap and dehumidification (if necessary) of air leaving the heap while also preventing heat loss from the heap that might adversely affect leach efficiency.

One or more of the insulative material layer(s) arranged at the top of the heap may cover the acidic liquor irrigation system depending on the most favoured configuration for the exchange of heat and/or water required between the heap, air, or oxygen containing gas, liquor and environment. For example, where sub-zero temperatures may be reached, freezing of the liquor may be prevented by placing the acidic liquor irrigation system under one or more insulative layers on top of the heap. Of course, it will be understood that only one insulative layer may be provided at the top of the heap.

Heated oxygen-containing gas including water vapour may be collected from a collection zone at the top of the heap and recycled, though a suitable conditioning system including pump or fan, humidifier, oxygen, carbon dioxide, and humidity sensors (as necessary), to a gas introduction portion of the aeration system located at or proximate the bottom of the heap or dump to reduce the amount of heat required to heat the temperature of the gas/vapour stream to the desired introduction temperature and saturation. Heaters may be employed, as necessary, to maintain the gas introduced to the heap at the desired temperature. Oxygen make-up with fresh air or oxygen input into the introduced gas may be employed as appropriate.

The ore containing chalcopyrite may contain other minerals such as the copper sulphides or minerals containing other desired metal values. The ore may be a mixture of ores; and the ore may be mixed with elemental sulphur, and/or pyrite especially where the chalcopyrite containing ore is mixed with secondary copper minerals such as, for example, malachite. Leaching from such ores is also to be promoted in accordance with the invention.

Generally, where the ore containing chalcopyrite; or the ore mixture containing chalcopyrite also includes acid-consuming minerals, such as carbonates, at least one of sulphur, pyrite and mixtures thereof may be added to the heap to compensate therefor as such sulphur or pyrite may be bacterially oxidised to a leaching sulphuric acid. Such oxidation may also act as a heat

generation source. If excess acid is generated, this may require to be neutralised, and the feasibility of doing this will depend on the cost of reagents and dumping space. However, in other cases, the additional acid may be useful for the treatment of other, acid consuming materials, which may be admixed with the heap or treated separately in other processes operating in parallel with the heap.

The ore may be primary crushed and/or subjected to secondary crushing to a size most suitable for heap leaching, preferably to a size between 3mm and 100mm.

Where other sources of chalcopyrite are used, such as tailings, these may have fine particle size. Such sources may be pelletised or agglomerated to the above particle size range so that they are suitable for heap leaching.

In another aspect of the invention there may be provided a heap leaching system in which the method as above described may be practiced. Such a system as well as including an aeration system, an acidic liquor irrigation system (with acidic liquor make-up system optionally being associated therewith), and a leachate collection system includes a heating/humidity control stage. The humidity control stage, which may include a humidification stage external to the heap as well as provision for gas heating, has the role of at least partly controlling saturation and temperature of the oxygen-containing gas introduced to the heap such that a substantial portion of the heap is maintained at a temperature such that thermophilic bacteria leach the chalcopyrite at an economically acceptable rate.

The heap may be insulated to minimise heat loss for the reasons described above. Any of the insulating techniques described above may also be conveniently employed.

With a method and system as described above, superior thermal/humidity control can be achieved in a heap leach of chalcopyrite containing material. Such control promotes the growth and maintenance of copper ore leaching microorganisms with better process efficiency and process economics.

Description of the Drawings

The invention may be more fully understood from the following description made with reference to the accompanying drawings in which:

Figure 1 is a flowsheet of a heap or dump leaching process operated in accordance with one preferred embodiment of the present invention; and

Figure 2 is a flowsheet of a heap or dump leaching process operated in accordance with a further embodiment of the present invention.

Detailed Description of the Drawings

The process of Figure 1 is directed to a heap leaching system 1 for treatment of a heap or dump containing chalcopyrite ore having formula $CuFeS_2$ grading 0.1 to 5% copper and 0.1 to 5 % sulphur as total sulphur.

Dump or heap 10 is made up of crushed rock including the chalcopyrite ore (possibly in admixture with other minerals) in a manner known in the art with some modification as described below. Heap or dump 10 is located on a pad or foundation 15 of concrete or some suitable water impermeable material which can support the heap or dump 10. The pad or foundation 15 is constructed with a slight slope to promote flow of leach liquor to a leachate recovery drain 20 forming part of a leachate collection system. Drain 20 may be located above or below natural ground level. The recovery drain 20 ultimately communicates with solvent extraction/electrowinning and copper recovery stage 400 which may be operated in accordance with conventional techniques. A portion of this stream may be recycled to the acidic liquor irrigation system 300 which may also receive acidic liquor make-up from acidic liquor make-up system 170.

Also located at or proximate the bottom of the heap or dump 10 is an aeration system comprising an array of aeration pipes 30 which are arranged to promote the flow of saturated air of controlled saturation and temperature through the heap or dump 10. Aeration pipes 30 may be of acid-resistant polymeric material, formed, in a gas introduction portion, with holes or apertures along their length to assist in uniform circulation of air throughout the heap or dump 10. Other aeration means could be provided. Portions of aeration pipes 30 may be appropriately insulated to prevent heat loss such that preferred gas introduction temperatures to heap 10 are maintained.

If necessary, provision may be made for heating the saturated air by optional heating means 140 to required temperature prior to introduction to the heap or dump 10. Introduction temperature, maintained by heating/cooling or control heat loss should exceed 40°C but not 60°C with a preferred temperature range of 45 to 55°C and a more preferred temperature of about 50°C.

The top 11 of the heap or dump 10 may be covered with an open curtain type or cover of material to minimise evaporative losses from the heap or dump 10. This cover may water impermeable. The top 11 of the heap or dump 10 may also be communicated with a collection zone 14 from which collection pipes 40 collect the air circulated through the heap or dump 10 for re-use in the heap or dump treatment process. Air circulation is created by fan or pump 60.

Accordingly, these collection pipes 40 communicate with aeration pipes 30 through a suitable fan or pump 60. The recycle ratio may be set up as required and additional fresh make up air or oxygen may be introduced through line 240 to the recycle air as necessary to maintain oxygen levels sufficient for bacterial respiration. Saturation may be controlled, at least in part, by control of the recycle ratio. Oxygen sensors could be employed to detect oxygen content of the recycle gas and make- up to set-point oxygen content conducted as required.

By example for an ore containing approximately 3% sulphur, each cubic metre of crushed rock making up the heap or dump 10 will typically contain 1.6 tonnes rock and, in the case of the chalcopyrite treatment process described, approximately 50 kg sulphur.

Chalcopyrite is bacterially oxidised according to the following reaction:

$$4\ CuFeS_2 + 17\ O_2 + 2\ H_2SO_4 \dashrightarrow 4\ CuSO_4 + 2\ Fe_2(SO_4)_3 + 2H_2O \qquad \text{(I)}$$

from which it is apparent that ferric ion may take part in the dissolution reaction.

In general terms, twice as much oxygen is required to oxidise 50kg of sulphur, therefore approximately 100kg of oxygen is required for each cubic metre of rock. This is equivalent to approximately 1500 m³ of air per tonne of rock at 25°C, after allowing for oxygen transfer efficiency. If another oxygen

containing gas, such as oxygen or oxygen enriched air, was used the volume would be commensurately lower. Fan 60 is appropriately selected to accommodate the ventilation rate required for the heap.

The oxidation reaction (I) releases heat in an exothermic process in quantity sufficient to heat the heap to about 70°C or higher if fully saturated air at 50°C is introduced to the heap.

Also arranged at top 11 of heap or dump 10 is an acidic liquor irrigation system 300 (communicating with an associated acidic liquor make-up system 170) which irrigates the heap or dump 10 with an acidic leach liquor containing the sulphur and/or iron oxidising bacteria. The liquor therefore contains water, sulphuric acid as well as bacteria and any additional nutrients that the bacteria may require. pH of the acidic liquor ranges from about 0.5 to 3, preferably about 0.5 to 2.5. To ensure that the leaching rate proceeds at a economically acceptable rate it may be necessary to adjust the redox potential of the liquor to a lower level.

Redox potential control can be achieved by removing some of the ferric iron sulphate produced in the leaching reaction by precipitation. The removal may be conducted by precipitating the iron with lime or limestone external to the heap or the conditions in the heap 10 may be controlled to allow precipitation. The redox potential (E_h) may preferably be reduced to approximately 400 to 450mV to achieve the required rate of leaching. Alternatively, some chalcopyrite ores will leach at an acceptable rate without reducing the redox potential. With these materials the removal of the ferric iron may not be necessary.

Extreme thermophilic bacteria of the *Sulpholobus* species are preferred and are cultivated, using known microbial cultivation techniques, and introduced to the heap or dump 10 with the acidic leach liquor or otherwise. *S. acidocaldarius* or *S.brierleyi* may be a useful species for the leach. Mixed cultures may be used. Further disclosure of the microbiology of the *Sulpholobus* micro-organism is provided in Chapter 12 (pp 279-305) of "Thermophiles: General, Molecular and Applied Microbiology", (1986), John Wiley and Sons, the contents of which are hereby incorporated herein by

reference. Other extreme thermophilic iron or sulphur oxidising micro-organisms may participate in the leach reaction. Alternatively the bacteria may be introduced to, or mixed with, the heap or dump 10 during formation.

As the preferred bacteria are extremely thermophilic, care is to be taken that the acidic liquor temperature does not fall below a value at which bacterial viability and growth is threatened. Heating and insulation arrangements to achieve this objective may be used at drain 20, top 11, and other locations, as necessary.

Heap or dump 10 temperatures are expected to be sufficiently high, given the exothermic nature of the sulphur oxidation reaction, that bacterial viability may be maintained provided that a continuous stream of saturated air is circulated through it. At the top 11 of heap 10, temperatures may exceed viable temperature even for extreme thermophiles. To avoid this, cooling air may be introduced through line 147 to lower the temperature to viable range. Line 147 may be provided with air from aeration system 30. Forced cooling may be conducted. The entry point may be at the point where temperature increases above the range at which bacteria are viable.

Air saturation is important to maintaining desired temperature range within heap or dump 10 as follows. Where temperatures rise above about 90°C, evaporation of water becomes appreciable and such evaporation consumes energy, that energy being the latent heat of vaporisation of water. Thus, the gas is capable, when necessary, of creating a cooling effect such that the local temperature may be maintained in the range 80 to 90°C at which extremely thermophilic bacteria maintain activity. This effect is most pronounced at full saturation of the air though some benefit may be achieved at lower humidity level.

Control of saturation of oxygen-containing gas at a desired level prior to introduction to the heap may conveniently be achieved by including a humidification stage 230 to humidify the air to the desired level of saturation. Operation of humidifiers for humidification of air, as such, is well described in the Chemical Engineering literature; see, for example, Perry et al *Chemical Engineer's Handbook*. The operation of such equipment may be controlled in

accordance with sensed humidity of gas collected from the top of the heap or dump 10. A number of humidification stages or humidifiers may be employed. Dehumidication may be allowed for. Heating may also be provided for in a heating/humidity control stage which may include heating and humidification/dehumidification stages as necessary.

Nevertheless, the exposed nature of the heap or dump 10 is such that heat losses at the sides of the heap or dump 10 require to be contained to maintain optimal growth of extremely thermophilic bacteria. Therefore, one or more insulative layers 50 are provided at the sides of the heap or dump 10 to minimise heat loss. Any insulating material, sufficiently durable to withstand climatic and process factors may be employed for this duty. Polymeric foams, such as polyurethane foams; or heavy plastic liners may be conveniently used for this purpose. Alternatively, naturally occurring insulating materials, such as straw, may be used. These layers may be water impermeable. Insulative layer(s) may overlie the acidic liquor irrigation system 300.

In a more specific embodiment, as shown schematically in Figure 2, the naturally occurring insulating materials may be inert substrate materials such as rock layers, for example of waste rock or rock overburden. Such waste rock layer(s)may be arranged in a base layer 100 at the base of heap 110; and a top layer 200 at the top of the heap 110 to "sandwich" the leachable ore in a layer 110a. Waste rock layers could also be arranged at the sides of the heap 10. Such a substrate may also act as a heat transfer medium providing zones for humidification of air entering the heap and loss of moisture from air exiting the heap 10. The substrate may also help to distribute gas and liquor flows which are counter-current in this embodiment.

In this embodiment, acidic leach liquor is applied to the top of the heap 110 using acid liquor irrigation system 300 in a conventional manner, as above described. Forced aeration of the heap 10 may be conducted through a pipe system 130 located at or proximate the base of the heap 10 as above described. Portions of pipe system 130 may be appropriately insulated to prevent heat loss such that preferred gas introduction temperatures are not maintained. As the air enters the waste rock layer 200, it will contact hot spent

acidic leach liquor draining from the active leach zone110a to be recovered by recovery drain 120. Consequently, it will become humidified and heated prior to entering the active leach zone 110a while the spent leach liquor and waste rock cools. In this way, the heap 10 itself may form at least part of the heating/humidity control stage.

Further, as the rising air enters the active leach zone 110a of heap or dump 10, it is pre-heated and substantially fully saturated with moisture so not to cause undesirable cooling of the leachable ore.

As the air moves upwards through the heap or dump 10, it enters the top layer 100 of inert waste rock, and meets incoming fresh cold acidic leach liquor moving downwards. Thus acidic liquor and oxygen-containing gas flow counter-currently through heap 10. The hot moisture laden air will now be cooled with heat and moisture transferred to the leach liquor which, in effect, is preheated before it moves downwards to enter the active leach zone 110a. Air may then be collected by pipes 140 for recycle to heap 110. If necessary, cooling air may be introduced to the top of heap 110 by line 147 to maintain temperatures in the bacterial viability range as described above.

In this manner, variations in leaching conditions within the active leach zone 110a which might adversely affect leach efficiency may be minimised or avoided with improved leach efficiency resulting.

In such a system, fluid losses as a result of air humidification may also be avoided. Further improvement may be achieved if supplemental insulation such as insulation blankets of suitable insulation materials (which should be acid-resistant) are used to provide insulation at the top and sides of the heap. Such a blanket may take the form of a plastic sheet or some other inert barrier with acceptable insulation properties. The blanket may be water impermeable.

Acid required for the process is introduced as required and may be produced when copper is extracted from solution, for example, in an electrowinning process by the reaction:

$$2\,CuSO_4 + 2\,H_2O \text{ ------> } 2\,Cu + O_2 + 2\,H_2SO_4 \qquad \text{(II)}$$

Sulphur or pyrite oxidation may also be used as a source of sulphuric acid.

Copper may be recovered from copper loaded acidic liquor directed through drain 20 at or proximate the bottom of heap 10, ultimately to solvent extraction/electrowinning stage 400. Prior to electrowinning, a solvent extraction operation may be conducted to recover copper sulphate from the leach liquors. Such solvent extraction operation does not interfere with acid production at the electrowinning stage. The solvent extraction and electrowinning stages may be operated conventionally.

It will be further understood that, while electrowinning is a suitable process for recovery of copper metal - though copper sulphate may in itself be a desirable product from the process - other processes for copper recovery, such as cementation, may be employed.

Modifications and variations may be made by a skilled reader following consideration of this disclosure and all such modifications and variations are intended to be within the scope of the present invention.

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. A method for heap leaching an ore containing chalcopyrite including the steps of:
   (a) introducing an acidic liquor containing iron or sulphur oxidising bacteria to a heap including chalcopyrite ore for contacting with the ore for liberating copper therefrom; and
   (b) introducing an oxygen-containing gas to the heap through an aeration system as a source of oxygen for the bacteria wherein the oxygen-containing gas introduced to the heap has saturation and temperature controlled to maintain a substantial portion of the heap at a temperature such that thermophilic bacteria leach the chalcopyrite ore at an economically acceptable rate.

2. The method of claim 1 wherein said substantial portion of the heap is maintained at a temperature in an extreme thermophilic range.

3. The method of claim 2 wherein said bacteria are *Sulpholobus* species.

4. The method of claim 1 wherein said substantial portion of the heap is maintained at a temperature in a moderate thermophilic range.

5. The method of claim 1 wherein oxygen-containing gas is heated by heating means prior to introduction to the heap.

6. The method of claim 2 wherein temperature of said oxygen-containing gas is maintained above about 40°C prior to introduction to the heap.

7. The method of claim 2 wherein said oxygen-containing gas is maintained at a temperature not exceeding 60°C prior to introduction to the heap.

8. The method of claim 7 wherein said oxygen-containing gas is maintained at a temperature in the range between 45°C and 55°C prior to introduction to the heap.

9. The method of claim 8 wherein said oxygen-containing gas is maintained at a temperature about 50°C prior to introduction to the heap.

10. The method of claim 4 wherein temperature of said oxygen-containing gas is maintained above about 30°C prior to introduction to the heap.

11. The method of claim 10 wherein temperature of said oxygen-containing gas is maintained in the range 35°C to 40°C prior to introduction to the heap.

12. The method of claim 1 wherein the top portion of the heap is cooled.

13. The method of claim 12 wherein cooling occurs through evaporation.

14. The method of claim 12 wherein cooling air is introduced to the top portion of the heap.

15. The method of claim 14 wherein cooling air is introduced at the point where temperature increases above the temperature at which said bacteria are viable.

16. The method of claim 1 wherein saturation of oxygen-containing gas introduced to the heap is controlled by a humidification control stage.

17. The method of claim 1 including the step of insulating the heap to minimise heat loss.

18. The method of claim 17 wherein at least one of the top and bottom of the heap is insulated.

19. The method of claim 17 or 18 wherein the sides of the heap are insulated.

20. The method of claim 17 wherein said heap is insulated by at least one layer of inert insulative substrate and an insulating blanket.

21. The method of claim 20 wherein said inert insulative substrate is waste or overburden rock.

22. The method of claim 1 wherein heated oxygen-containing gas including water vapour is collected from a collection zone at the top of the heap and recycled through a conditioning system to a gas introduction portion of said aeration system located at or proximate the bottom of said heap.

23. The method of claim 1 wherein said ore containing chalcopyrite contains other sulphidic minerals containing desired metal values.

24. The method of claim 1 wherein said ore containing chalcopyrite is a mixture of ores.

25. The method of claim 24 wherein said mixture of ores further includes at least one of elemental sulphur, pyrite and mixtures thereof.

26. The method of claim 25 wherein said mixture of ores includes secondary copper minerals.

27. The method of claim 1 wherein acidic liquor and oxygen-containing gas flow counter-currently through the heap.

28. A heap leaching system including:
    (a) a heap of an ore including chalcopyrite;
    (b) an acidic liquor irrigation system for irrigating said heap with an acidic liquor containing iron or sulphur oxidising bacteria to contact with the ore for liberating copper therefrom;
    (c) a leachate collection system;
    (d) an aeration system for introducing an oxygen containing gas to the heap as a source of oxygen for the bacteria;

    wherein a heating/humidity control stage at least partly controls saturation and temperature of oxygen-containing gas introduced to the heap such that a substantial portion of the heap is maintained at a temperature such that thermophilic bacteria leach the chalcopyrite ore at an economically acceptable rate.

29. The system of claim 28 wherein said heap includes an insulation layer to minimise heat loss.

30. The system of claim 28 or 29 further including a collection zone at the top of the heap from which heated oxygen-containing gas including water vapour is collected, the collection zone communicating with a conditioning system through which said oxygen-containing gas is recycled to a gas introduction portion of said aeration system located at or proximate the bottom of said heap.

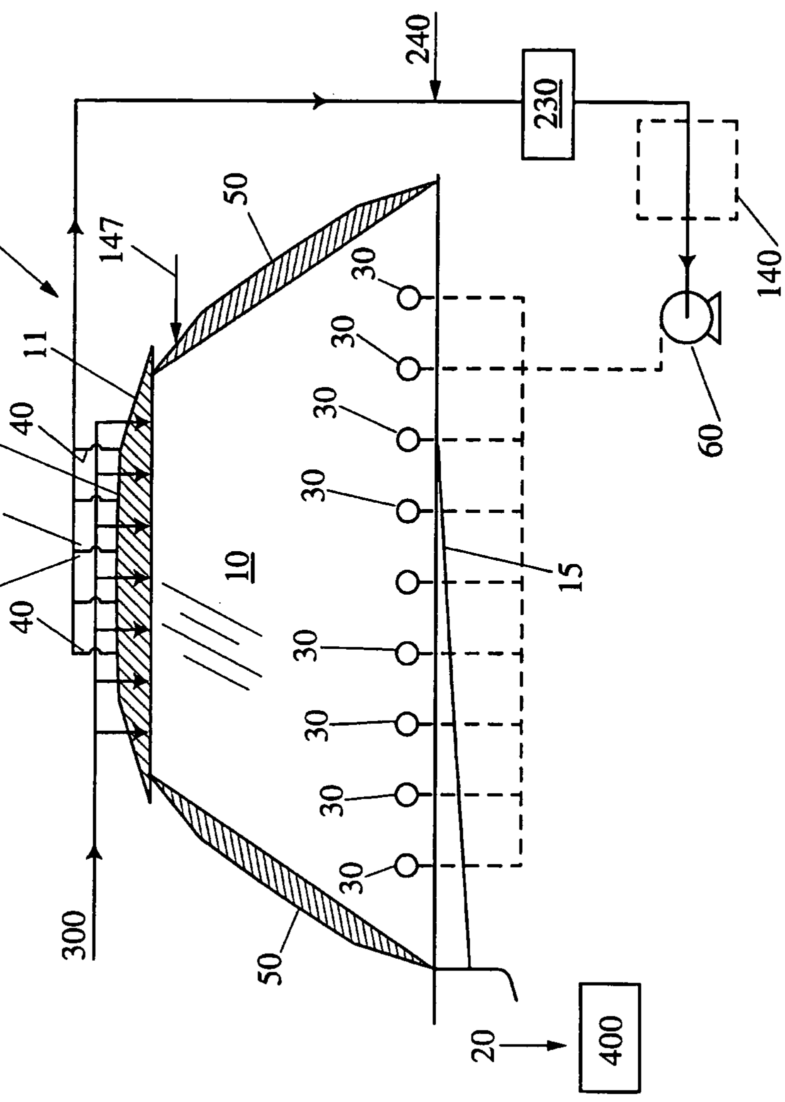

Fig 1.

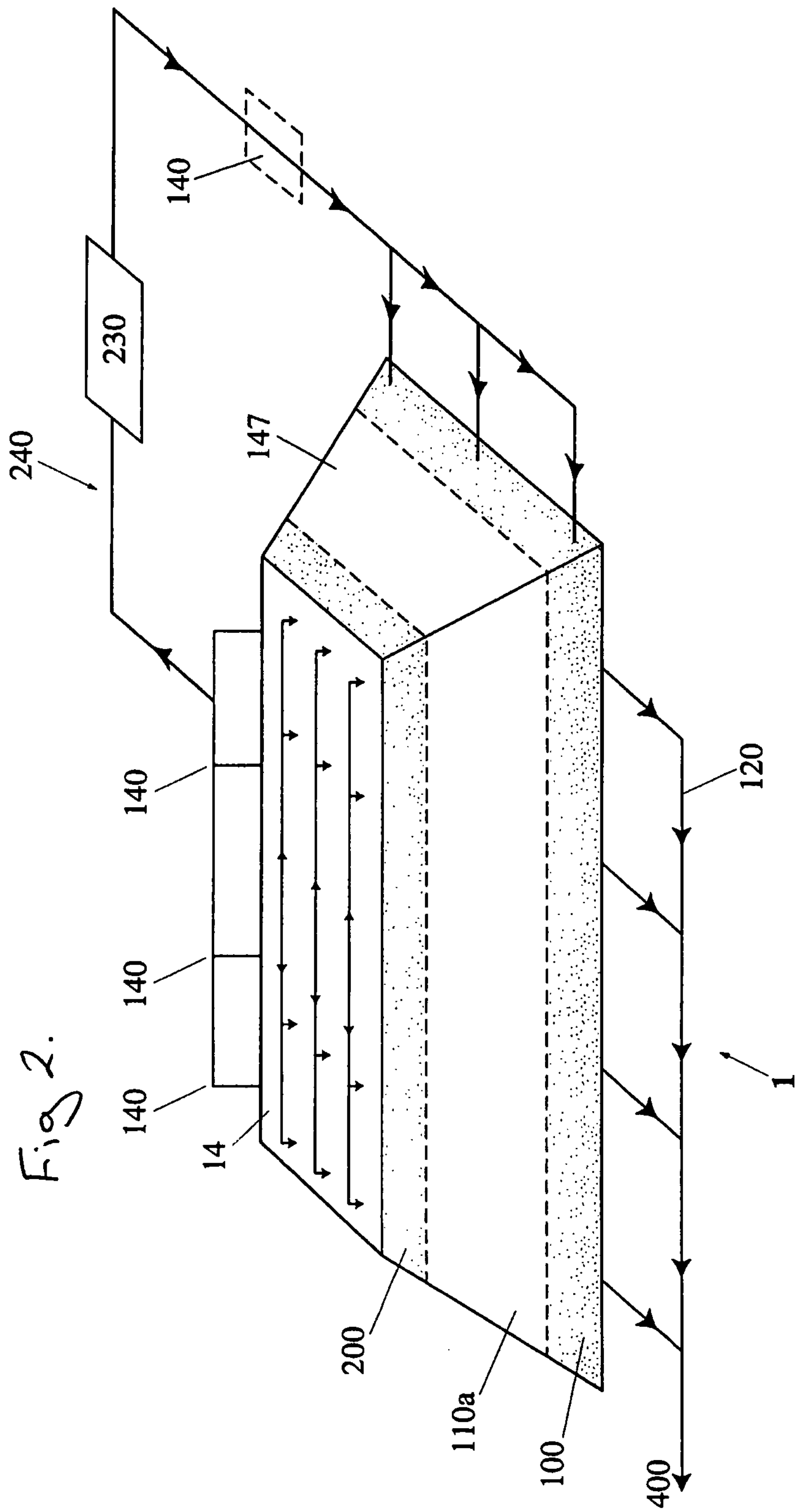

Fig 2.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU00/00442

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl. [7]: C22B 003/18, C22B 003/00, C22B 015/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC[7] AS ABOVE

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
Derwent WPAT: IPC[7] as above + bacter+ + micro organism+ + sulpholobus + sulfolobus + thiobacillus + leptospirillum

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4571387 A (Bruynesteyn et al) 18 February 1986 Whole Document	
A	AU 78560/98 A (University of Queensland; MIM Holdings Ltd) 11 February 1999 Whole Document	
P, A	AU 18524/99 A (Placer Dome Inc) 16 December 1999 Whole Document	

[X] Further documents are listed in the continuation of Box C [X] See patent family annex

* Special categories of cited documents:
"A" Document defining the general state of the art which is not considered to be of particular relevance
"E" Earlier application or patent but published on or after the international filing date
"L" Document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" Document referring to an oral disclosure, use, exhibition or other means
"P" Document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
31 May 2000	19 JUN 2000

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU00/00442

C (Continuation).	DOCUMENTS CONSIDERED TO BE RELEVANT	
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 9851827 A1 (Echo Bay Mines Limited) 19 November 1998 Whole Document	
A	EP 522978 A1 (Newmont Mining Corporation) 13 January 1993 Whole Document	

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/AU00/00442

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member					
US	4571387	CA	1214043				
AU	78560/98	NONE					
AU	18524/99	NONE					
WO	9851827	AU	76709/98	US	5873927		
EP	522978	AU	18687/92	BR	9202534	CA	2073589
		MX	9203974	TR	26634	US	5332559
		ZW	106/92	US	5834294	ZA	9204825
		US	5246486				

END OF ANNEX